TWELVE

Human Factors in International Keyboard Arrangement

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Guidelines have recently been formulated to help in the design of business equipment keyboards for effective operator use (Alden, Daniels, & Kanarick 1970; Seibel 1972). These guidelines recommend assigning the primary alpha and/or numeric key cluster(s) to a central location and distributing the remaining keys with their specialized symbols, controls, and functions around the periphery of the central cluster(s). The alpha and numeric key placements usually conform to historical precedents and accepted national standards. The peripheral placement of keys is guided by such principles as frequency of use, importance, functional relationships, sequence of use, and historical precedent.

These guidelines have been used with reasonable success to configure keyboard equipment the operation of which is limited to a single and well-defined cultural group. But are these same guidelines valid when a keyboard is designed for users representing different nationalities, languages, and cultures? Or must the designer consider additional, sometimes conflicting, guidelines?

SOME PROBLEMS IN DESIGNING KEYBOARDS FOR INTERNATIONAL USE

The problems in designing business equipment keyboards for more than one nation or cultural region are complex. The designer must consider the application requirements in each region, historical precedents, and accepted and proposed national standard arrangements. These considera-

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tions may be complicated by cultural and language variations, by international standards, and by manufacturing pressures to minimize the number of different keyboard arrangements for a given product.

Keyboards range in size from the 13-key array found on simple adding machines to the more than 220-key arrays required to generate in excess of 3,200 characters on some Kanji language teleprinters. A keyboard may have only a ten-key numeric cluster and a few function keys. Or, it may contain control keys, function keys, a separate full-key matrix numeric array, and a cluster containing alpha, numeric, punctuation, and symbol keys.

The keyboard characters may be in any one of such diverse languages as Arabic, English, Greek, Hebrew, Kanji, Katakana, or Russian. Even countries that share a common basic alphabet differ in their requirements for characters. For example, some require special characters to handle regional peculiarities, diacritical marks to provide proper phonetic emphasis, and unique alpha character arrangements based on historical precedent.

To add to the problems already enumerated, a number of international and national standards recommend keyboard arrangements for some types of machines, but the several standards do not all agree.

Manufacturers, of course, prefer to minimize the number of specialized keyboards they are required to produce for a given machine. Each additional kind of keyboard costs money for tooling, manufacture, inventory, shipping, and the preparation of specialized training and maintenance manuals.

Finally, organizations purchasing business equipment are interested in commonality among keyboards, where practical. Keyboard commonality facilitates the exchange of operators within and across national boundaries and minimizes the requirements for operator training and retraining. However, the advantages of commonality are lost if it produces significantly higher machine cost or poorer operator performance than would be possible with a specialized arrangement.

KEYBOARD ARRANGEMENT: NATIONAL

GUIDELINES

Guidelines to help the designer in arranging the keys on a keyboard (Alden et al. 1970; Seibel 1972) have developed primarily from experiences within single and well-defined national and cultural groups. They do not consider the problems associated with international operation. These national guidelines consist of at least ten rules:

1. *Determine the characters and number of keys required.* The specific alpha, numeric, symbol, punctuation, function, and control characters needed for all the intended uses of the system, and the number of keys required to contain the characters, should be determined by analyzing the machine application requirements.

2. *Arrange the keys according to their frequency of occurrence and according to operator characteristics.* Within a language, individual characters and character sequences occur with differing frequencies. Since the several fingers of the hand are not equally strong, keys should be arranged to take advantage of the strengths of certain fingers and to minimize the impact of the weaknesses of others. That is, the most frequently used characters should be located so that the stronger fingers and hand do more of the work. The arrangement of the keys should, however, allow an operator to alternate between the two hands during touch operation, since maximum speed of entry occurs with such hand alternation.

3. *Follow historical precedent.* The adage, "Do not change something unless there is a good reason," is the foremost principle in arranging the touch area of a keyboard. Since operators may have had previous experience with other keyboards, the layout should permit maximum possible transfer of experience. Most users are not willing to accept a new keyboard arrangement for a machine that performs the same basic functions as their previous equipment, unless the advantages of the new arrangement greatly outweigh the retraining problem that will result from its adoption. This guideline pertains primarily to the touch-operated region; the resistance to change is not nearly so strong for areas where visual search is normally required to locate the desired key.

4. *Follow established standards.* National standards for keyboard arrangement have been issued for some machines. Such standards should be followed unless there are good reasons to deviate.

5. *Group frequently used keys in the touch area.* In touch operation, the key position or value does not have to be verified visually. Touch-operated keys are located in the normal "home" or resting hand position, where they may be easily operated with minimum fatigue and strain. Frequently used keys should be arranged and located to facilitate touch operation. In many business equipment machines, typewriter and/or numeric groupings comprise the most frequently used keys. For that reason, they are often placed in the optimum touch area.

Function, control and symbol keys may be positioned for touch operation if they have high frequencies of use. Such keys are usually placed around the typewriter and/or numeric key cluster(s). Keys used less frequently should be placed in less accessible peripheral locations.

6. *Group common functions together.* Keys representing related functions should be grouped in close proximity to each other; for example, the keys containing the symbols for open and close parentheses should be located adjacent to each other.

7. *Group logically and according to sequence of use.* Keys should be placed in a sequence that reflects a normal and logical sequence of operation. For example, the "open parenthesis" should be placed on the key to the left of the "close parenthesis," at least in countries where the sequence of entry is left to right.

8. *Locate according to importance.* If the consequence of inadvertent key operation is great, locate the key in a peripheral location. Provide a lock on the key if greater protection is required. Keys critical to the completion of a task should normally be located according to other guidelines. Unique coding may be utilized to provide extra emphasis.

9. *Code the keys.* Key tips should be coded uniquely to facilitate the recognition of logical groupings of keys, keys of special importance, and keys that are operated with high frequency. Coding techniques include key size, shape, color, surface texture, caption style, direction of movement, and spacing.

10. *Consider all factors.* In arriving at the final arrangement, consider all relevant factors: frequency of occurrence and importance of each machine application, location and space available for the keyboard, costs, and manufacturing requirements. A trade-off study between alternatives may be necessary to define the best layout.

In principle, following the rules above should result in a keyboard providing best possible operator performance. In practice, the rules sometimes conflict. For example, following a historical precedent for the alphabetic characters (rule 3) would eliminate the possibility of grouping alpha characters according to their frequency of occurrence in the language and according to the strengths of the fingers and hands (rule 2). In other words, the guidelines cannot be followed cookbook style.

ALPHABETIC ARRANGEMENT

A great deal of controversy over keyboard arrangements has been generated by the second and third guidelines above. In particular, attempts have been made to introduce touch layouts not in agreement with previous operator experience. It is important to review this effort because of the special problems of acceptance that arise when touch arrangements for alphabetic and numeric characters deviate from those established through long usage.

The QWERTY keyboard arrangement, so called because these are the six keys in the upper left-hand part of the keyboard, has become the accepted layout in the United States and certain other countries for typewriters and for communication and data processing machines requiring alphanumeric data entry. Attempts to introduce alternative arrangements have been relatively unsuccessful for applications involving touch operation.

The Simplified Keyboard, developed by Dvorak (Dvorak, Merrick, Dealey, & Ford 1936), is supposed to be scientifically arranged on the basis of the frequency of use of letters, letter patterns and sequences in the English language. A study by Strong (1956) for the U.S. government compared performance on the Dvorak keyboard with the QWERTY arrangement. The results are often cited as a major reason for not changing the

QWERTY layout. Strong found that when experienced typists used the Simplified Keyboard, they required an average of 100 hours of retraining to achieve their original gross rate of speed. He concluded that the results of the comparison did not justify adoption of the Dvorak keyboard for use by the U.S. government. Mettler (1971) reports that similar scientifically derived arrangements have been undertaken for other languages and that the results are different in every instance, because the frequencies of the individual letters and their sequences vary in each language.

Another possible arrangement is an alphabetical sequence from A to Z, the so-called ALPHA arrangement, used on some stockmarket inquiry terminals. Results of two recent studies (Hirsch 1970; Michaels 1971) do not provide evidence that supports the selection of the ALPHA arrangement in preference to the QWERTY layout, at least for nonrandom code inputs. In the Hirsch study, subjects unskilled in typing used either an ALPHA or QWERTY keyboard to enter familiar names and some numbers. Initial performance was better on the QWERTY arrangement, and this difference was maintained after equivalent amounts of practice.

Michaels compared performance on the two keyboards with skilled, semiskilled, and unskilled typists. The input material was a list of names and addresses taken from telephone directories. He found that keying rates and work output were greater for skilled and semiskilled typists on the QWERTY keyboard. Performance on the two keyboards was essentially equal for unskilled typists. The superior performance by skilled and semiskilled typists on the standard typewriter is probably explained by their previous experience. Interference and conflicting motor responses probably occurred when these subjects used the ALPHA arrangement.

Other keyboard designs, such as chord keyboards, provide alternative configurations. Chord keyboards, which require the simultaneous depression of two or more keys, greatly increase the number of different codes that can be entered in a single movement. With 10 keys, 1,023 different codes are possible (Klemmer 1971). Conrad and Longman (1965), and Bowen and Guinness (1965) provide descriptions and experimental comparisons among chord keyboards and more traditional ones. A comprehensive review of chord keyboards and other entry devices has been prepared by Seibel (1972).

Still other keyboards of unique design have been proposed from time to time. For example, Kroemer (1972) has tested a typewriter keyboard designed to minimize unnatural, uncomfortable, and fatiguing body and arm postures. Keys on the keyboard are arranged in two hand-configured groupings—one for each hand. Keyboard sections allotted to each hand are physically separated to facilitate positioning of the fingers, and are inclined laterally to reduce muscular strain.

Why have QWERTY keyboard arrangements retained their popularity, even when some other keyboards have shown performance advantages?

Michaels (1971, p. 425) provides a succinct answer: "Probably because skill in using QWERTY is so widespread." Surveys of job skills in some American cities show that about 50 percent of the working-age population uses a typewriter for some purpose. This figure will become larger with the increased emphasis on typing in schools and the growing use of keyboard terminals for entering data into computer systems. Michaels (1971) reports that about 2.3 million typewriters are sold yearly, and there are about 45 million typewriters existing in the United States. Ancona, Garland, and Tropsa (1971) estimate that in a few years nearly two million keyboard devices will be in use in the United States alone for communication purposes and for direct computer processor entry.

Such widespread experience and skill with the QWERTY keyboard makes retraining a formidable barrier to any alternative proposal. If all keyboards were replaced with a new version, all operators would require retraining. If only part of the keyboards in an office were changed, the hiring and assignment of trained personnel would be more complicated, and restrictions on the interchange of machines during equipment malfunctions could raise significant problems.

The gradual erosion of interest in the Dvorak layout demonstraies that an alternative must have more than publicity and staunch supporters to overcome the training and acceptance obstacles. According to Mettler (1971), nonstandard arrangements have fared no better in other countries than in the United States. To be accepted, any new alpha keyboard layout must demonstrate significant advantages in performance, minimum retraining time, and an initial learning rate equivalent to or better than that possible with the QWERTY configuration. Even with such well-documented justification, new layouts may not be accepted by manufacturers and users.

NUMERIC ARRANGEMENT

There are two common digit arrangements for ten-key keyboards. The adding machine arrangement has the numbers 7, 8, and 9 on the top row; 4, 5, and 6 on the middle row; and 1, 2, and 3 on the bottom row. The touch tone telephone configuration has the 7, 8, and 9 keys interchanged with the 1, 2, and 3 keys. Other layouts have been tested (e.g., Conrad 1966; Deininger 1960), but generally discarded. Hanes and Baker (1965) concluded that experienced touch operators would have essentially equivalent performance with either configuration if they did not transfer between numbering schemes. Transfer might cause interference, reducing the speed of entry, accuracy, or both. The touch system is based on an operator's developing an almost automatic set of arm, hand, and finger movement patterns in response to the numbers to be entered on a particular keyboard. Requiring an operator to enter the same numbers on a keyboard with a different numbering arrangement would probably force him to suppress one

movement pattern and develop another. There are no reports in the general literature on such transfer experiments involving skilled operators.

An experiment by Conrad and Hull (1968) found that, for initial performance by completely inexperienced subjects, the touch tone layout had a small and nonsignificant speed advantage, and a highly significant accuracy advantage compared to the adding machine arrangement.

The widespread adoption of touch tone telephones means that many people will have had previous experience on the touch tone arrangement when they come to a work situation. The impact of this previous experience on learning the configuration on adding machine keyboards is not known. Nor do we know the magnitude of the retraining problem that would arise if one layout were adopted as a universal standard, or the magnitude of the interference that might occur if both layouts existed in the same office and an operator were required to operate both.

Chord keyboards have been used in some post office letter-sorting machines, both in the United States and in the United Kingdom. Some of these machines are apparently being modified by having their chord keyboards replaced with sequential entry keyboards. Reports documenting the reasons for this change are not generally available.

The full-key matrix keyboard is another numeric arrangement in such widespread use that it has become a de facto standard, at least in the business equipment field. The number of key columns provided is usually dependent on the application.

A Belgian Post Office study (Bertelson & De Cae 1961) compared the performance of two groups of experienced operators, one group skilled on the ten-key keyboard and the other skilled on the matrix array. The results showed the ten-key unit to be faster, even when as many as 45 percent of the digits were zero. No differences in error rates were found between the two keyboards.

Full-key matrix keyboards are being provided on many machines, even though Seibel (1972), based on a review of research results, concluded that the ten-key array is preferred for skilled and unskilled operators. The retraining problem is often given as a reason that full-key units on new products are not replaced by ten-key numeric keyboards.

NATIONAL STANDARDIZATION

Keyboard standardization is in progress at both national and international levels. National standardization bodies usually develop and approve keyboard standards for their respective countries. The names and addresses of the national bodies are available from the International Standards Organisation (ISO).[1]

[1]Requests for information concerning the work of ISO should be addressed to: ISO Central Secretariat, 1, rue de Varembé, 1211 Genève 20, Switzerland.

The United States group is the American National Standards Institute (ANSI) (Ancona et al. 1971). It has issued at least three standards relating to keyboards:

1. *American Standard—Typewriter Keyboards, X4.7-1966 July 1966.* This Standard prescribes the arrangement of the 42 basic printing keys on the typewriter; the characters, upper and lower case, that appear on the keys; and the 2 shift keys and space bar. An electric typewriter keyboard is preferred, and a manual typewriter keyboard is specified as an alternate.

2. *USA Standard—10-Key Keyboard for Adding and Calculating Machines, X4.6-1966, September 1966.* This standard prescribes the arrangement of the ten numeric keys for adding and calculating machines of the ten-key type.

3. *American National Standard—Alphanumeric Keyboard Arrangements Accommodating the Character Sets of ASCII and ASCSOCR, X4.14-1971, March 1971.* The two arrangements defined are intended for typewriter-like data communications and data processing alpha-numeric keyboards implementing the character sets of the American Standard Code for Information Interchange (ASCII) and the American Standard Character Set for Optical Character Recognition (ASCSOCR).

An ANSI Standard represents a consensus of those substantially concerned with its scope and provisions. It is a guide; it does not preclude anyone from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard.

Other national standardization bodies are also involved in establishing keyboard standards. For example, the British Standards Institution (BSI) has published adding machine (BS 1909: 1963) and typewriter (BS 2481: 1961) standards (Whitfield 1971). The Japanese Industrial Standards Committee has issued Standard JIS B9509-1964, establishing a Katakana typewriter layout. Both the Canadian Standards Association and the Deutscher Normenausschuss are known to have circulated proposals for keyboard standards.

Sometimes groups other than a national standardization body may establish their own keyboard standards. For example, the United States Department of Defense (1969) has published a military standard on keyboard arrangements.

GUIDELINE EVALUATION

It is difficult to measure the success of guidelines and standards for key arrangement, since very few published studies deal with that issue. The human factors group at National Cash Register has, however, completed several proprietary investigations on a number of alternative keyboard layouts. Specifically, keyboard arrangements developed by following guidelines were compared with other layouts developed both within and

outside the company. The results showed that operator performance is better on keyboards that follow guidelines than on those that do not.

KEYBOARD ARRANGEMENT: INTERNATIONAL

INTERNATIONAL KEYBOARD VARIATIONS

Keyboards for international use must consider differences between nations and cultures. At the very least, basic alphabets, such as Arabic, Greek, Hebrew, Katakana, and Roman, must be accommodated. Even within a single alphabet, special symbols and characters are required to satisfy variations peculiar to some cultures and languages. In addition, common characters within a basic alphabet may be assigned to different positions on a keyboard for historical reasons.

A comparison of international keyboards designed for one type of application, accounting, illustrates some of the differences that may occur among various countries and regions. Figure 1 shows the basic keyboard arrangement for the recently released (1972) NCR 399 accounting system. Figures 2 to 10 illustrate alternative keyboards offered as standard for 17 countries or regions. Still other variations are possible by special customer order. The key clusters in Figure 2 to 10 have been rearranged to accommodate graphics of maximum size on the key tips. The key clusters for all regions are arranged as shown in Figure 1.

Figures 11 to 14 show the keyboard arrangements for the NCR 395 accounting machine designed for four different countries, and Figure 15 shows the keyboard arrangement for the NCR 33 accounting machine designed for Turkey.

Differences among basic alphabets can be seen by comparing characters on the English (Fig. 3), Japanese Katakana (Fig. 10), Arabic (Fig. 11), Hebrew (Fig. 13), and Greek (Fig. 14) keyboards. Even within common alphabets, language differences require different keytip captions. For example, "Load" on the South African keyboard (Fig. 4) is "Laden" on the German configuration (Fig. 6), and "Charg" on the French version (Fig. 5).

Several of the figures reveal differences in character locations within the same basic alphabet. For example, the QWERTY sequence on the American keyboard (Fig. 1) is AZERTY on the French keyboard (Fig. 5), and QWERTZ on the German layout (Fig. 6). Other differences are readily apparent in the figures. Frequency of use and historical precedents are the primary reasons for the differences among countries.

The requirement for additional characters within a basic alphabet to satisfy national requirements is illustrated by the Ã, Ñ, and Õ characters found on the Spanish keyboard (Fig. 2). These characters are not required on the American version (Fig. 1).

Some symbols are required in one country, but not in another; for example, the # symbol is used on the keyboard for the United States

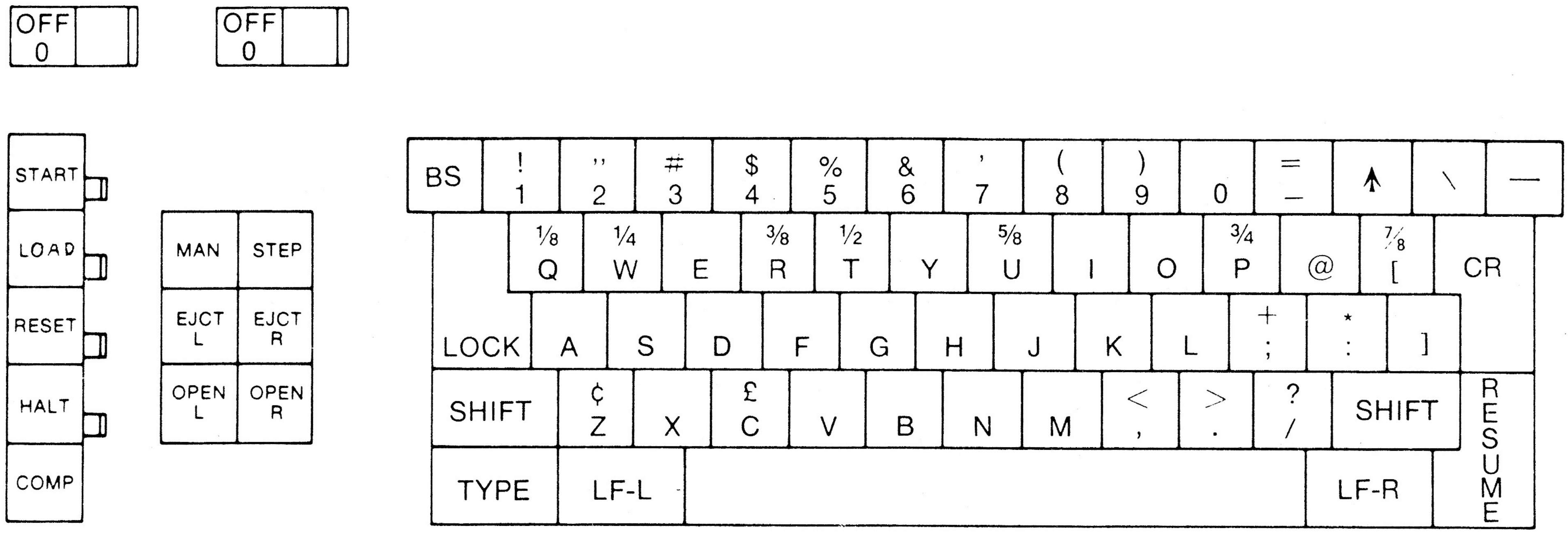


Fig. 1. NCR 399 U.S. keyboard arrangement.

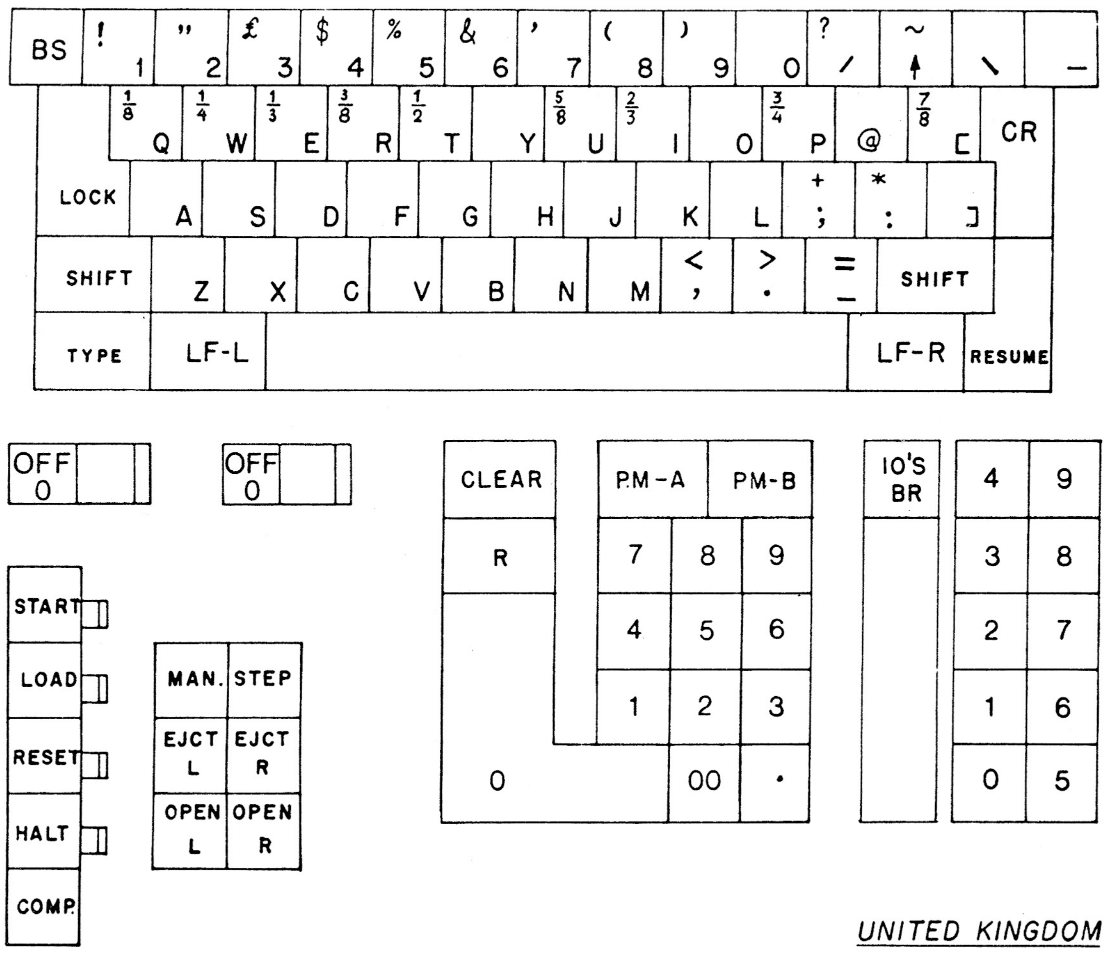


Fig. 3. NCR 399 keyboard for United Kingdom.

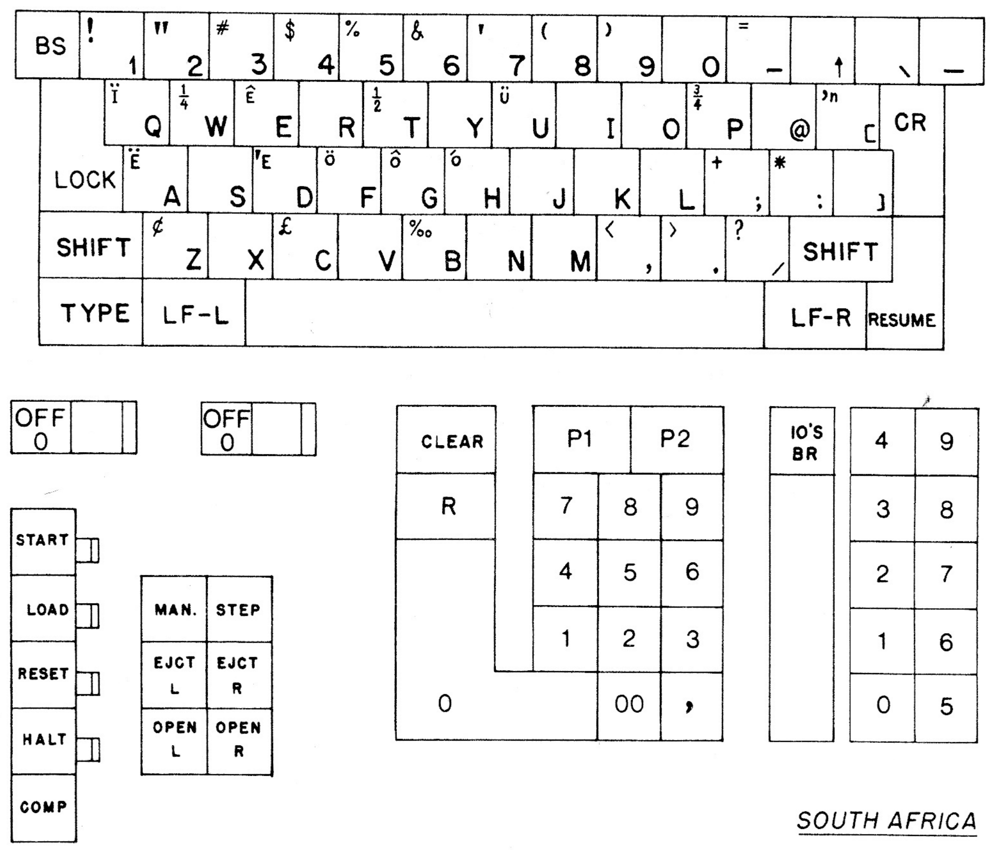


Fig. 4. NCR 399 keyboard for South Africa.

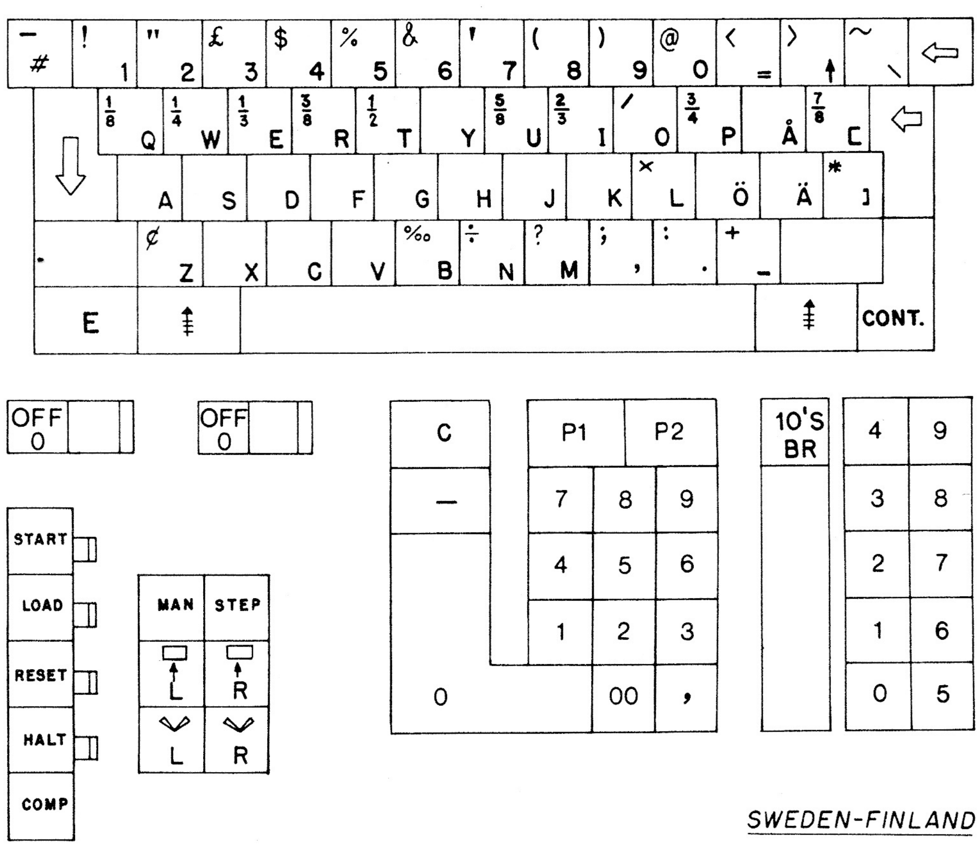


Fig. 7. NCR 399 keyboard for Sweden and Finland.

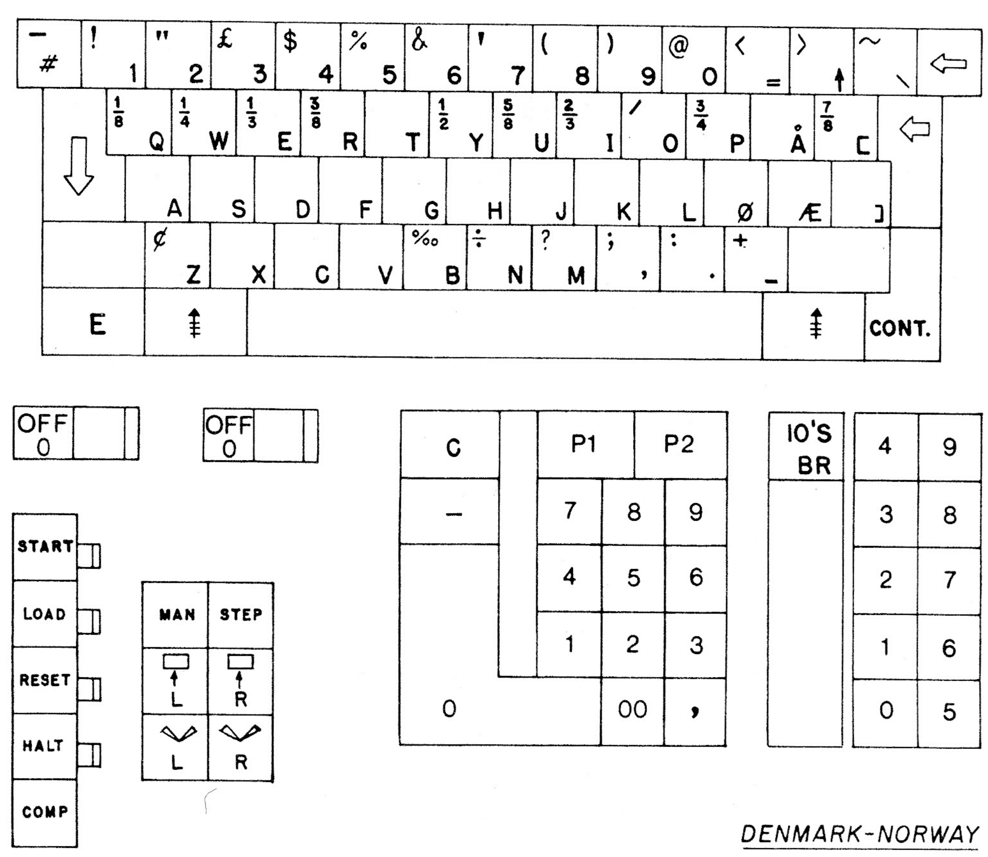
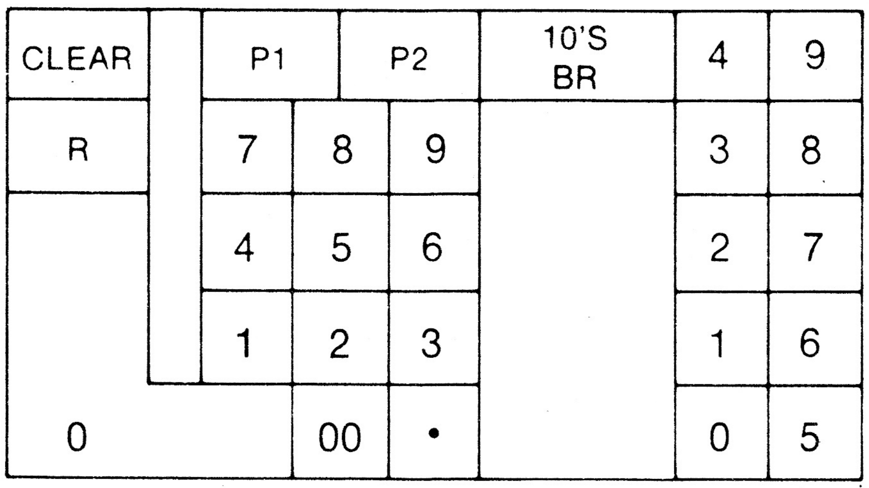


Fig. 8. NCR 399 keyboard for Denmark and Norway.



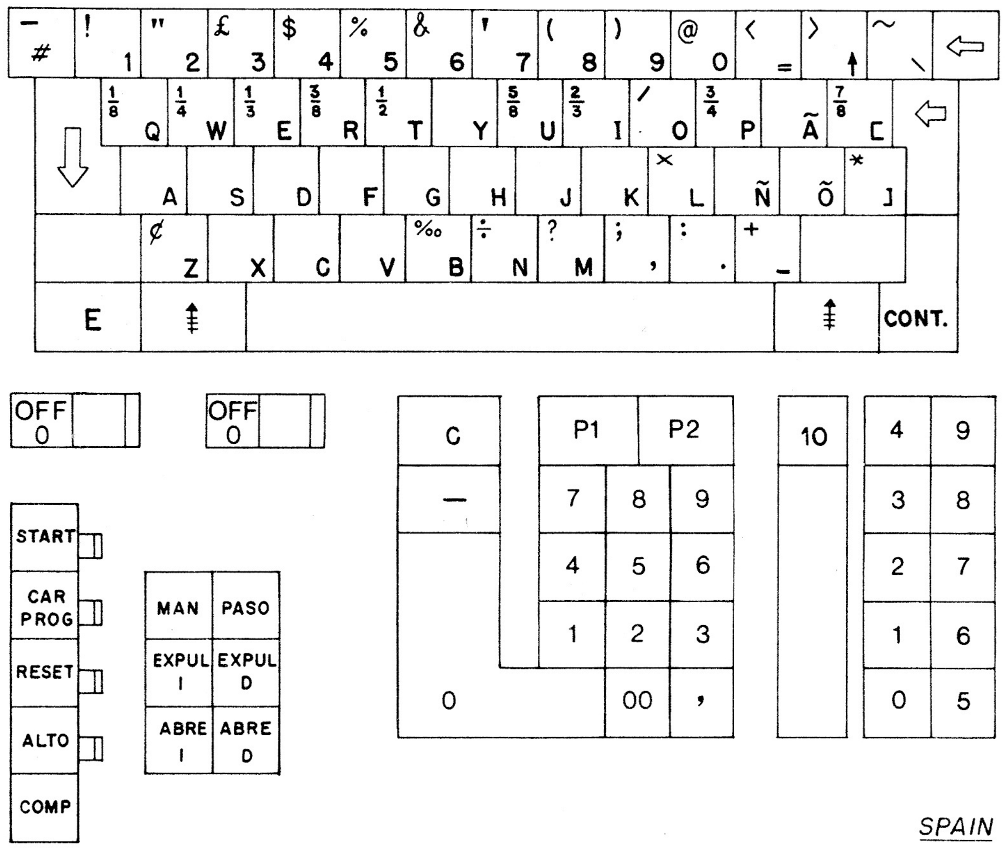


Fig. 2. NCR 399 keyboard for Spain.

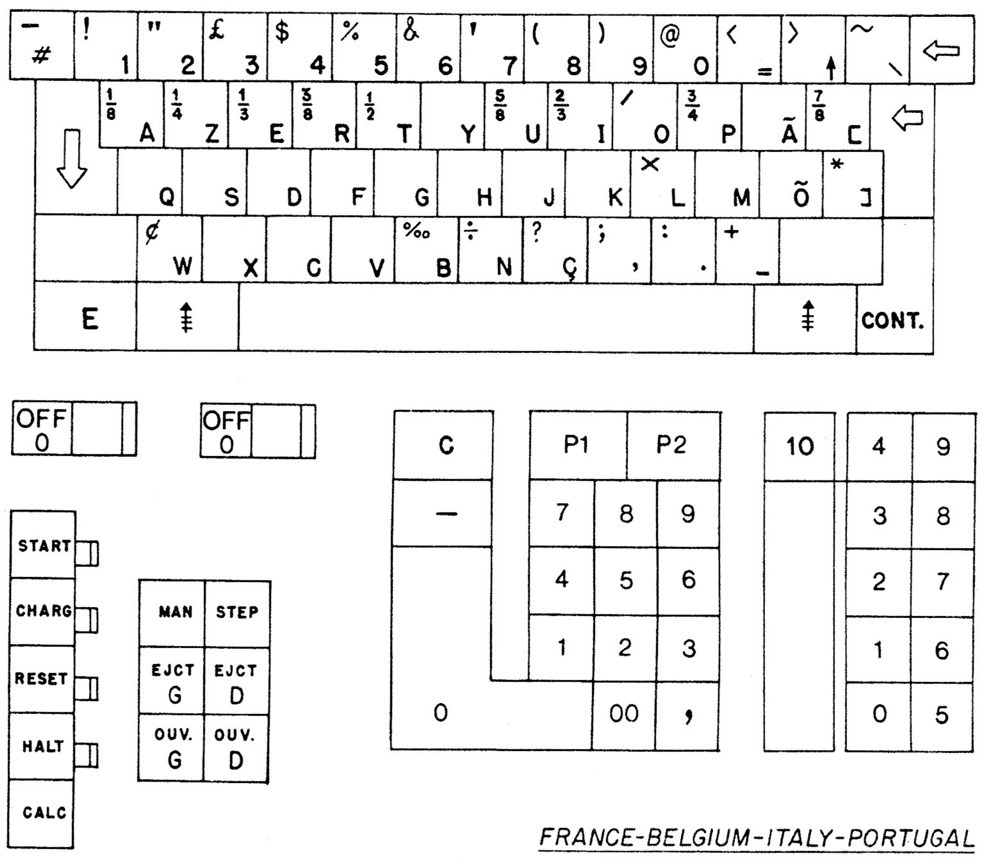


Fig. 5. NCR 399 keyboard for France, Belgium, Italy, and Portugal.

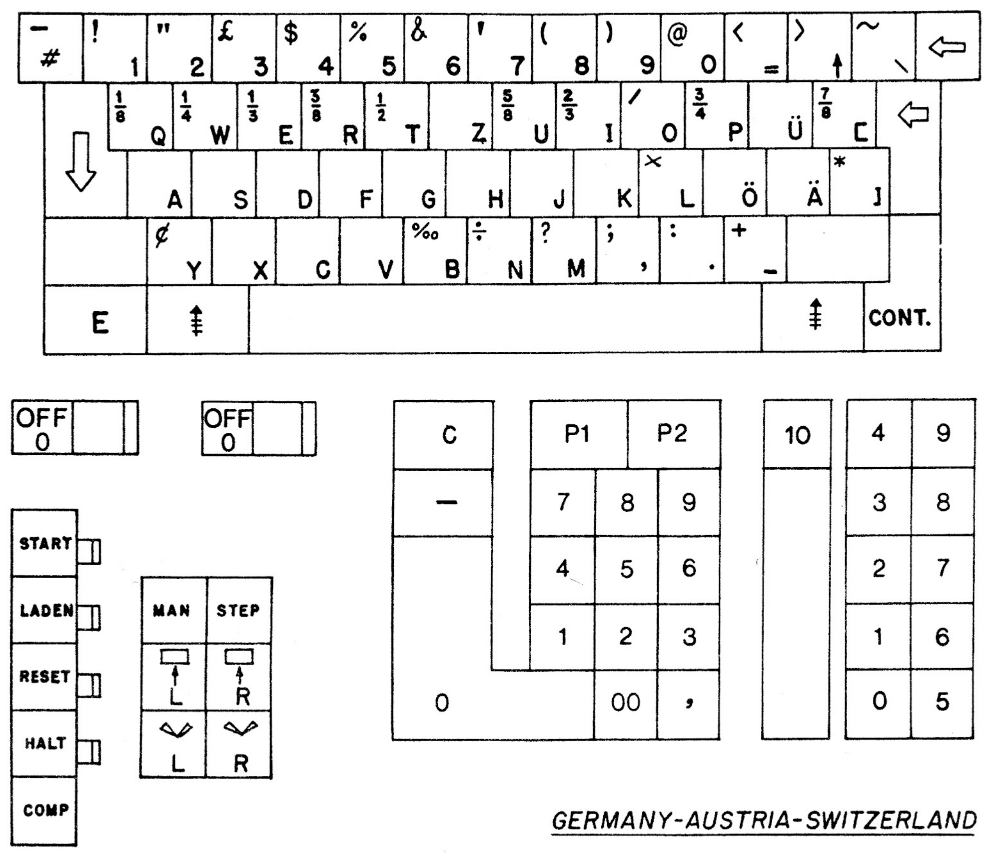


Fig. 6. NCR 399 keyboard for Germany, Austria, and Switzerland.

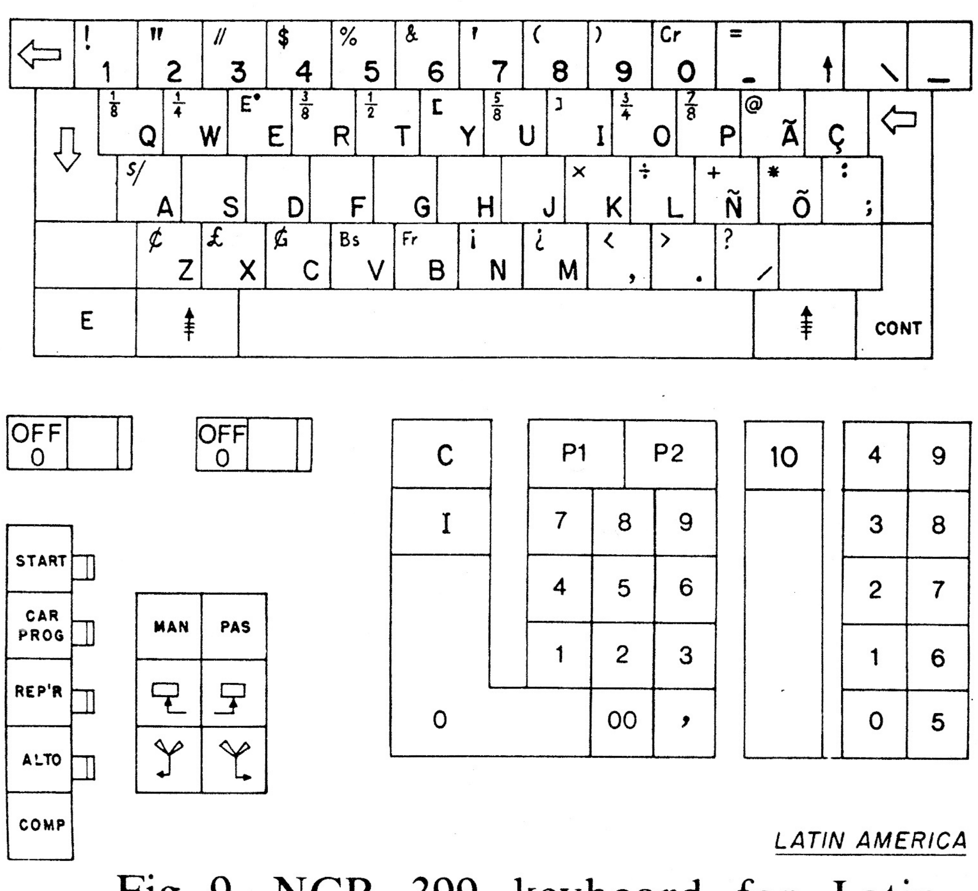


Fig. 9. NCR 399 keyboard for Latin America.

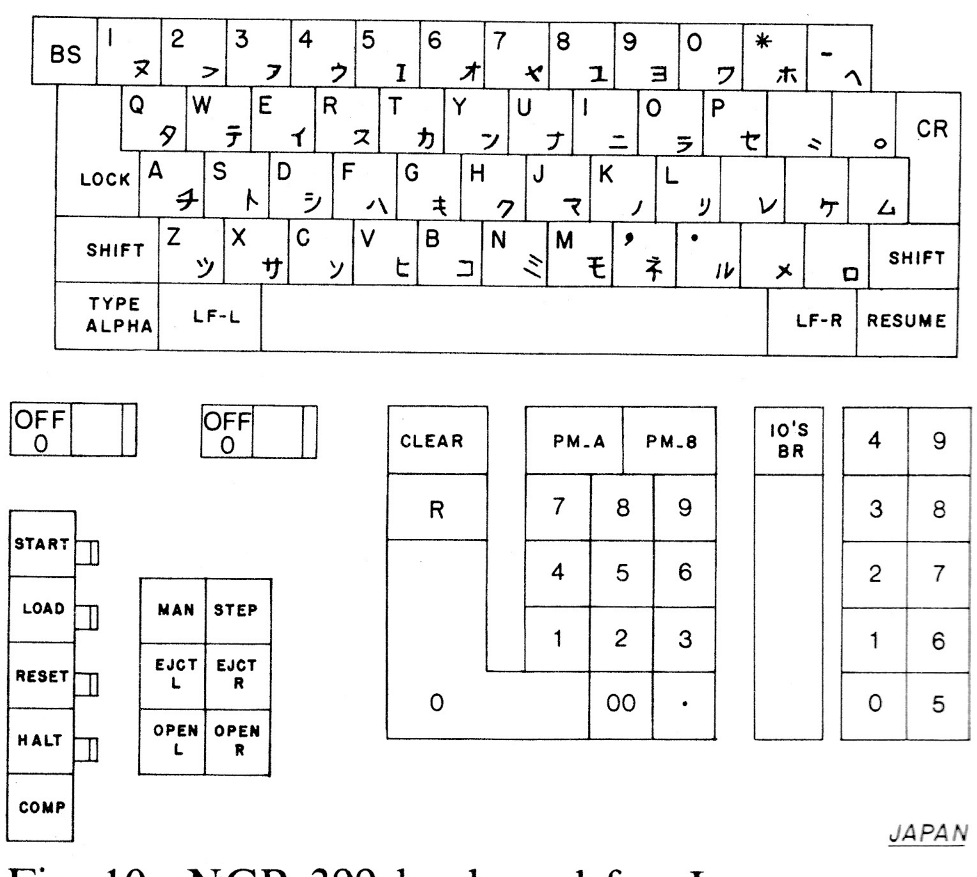


Fig. 10. NCR 399 keyboard for Japan.

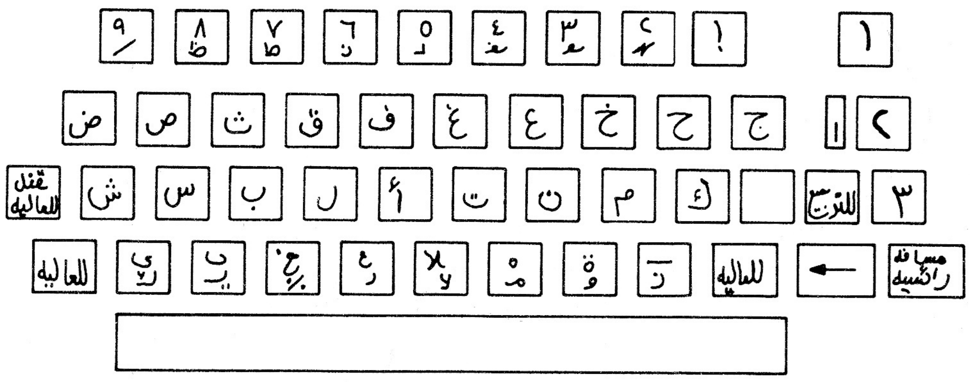


Fig. 11. NCR 395 typewriter keyboard for the Arabic language.

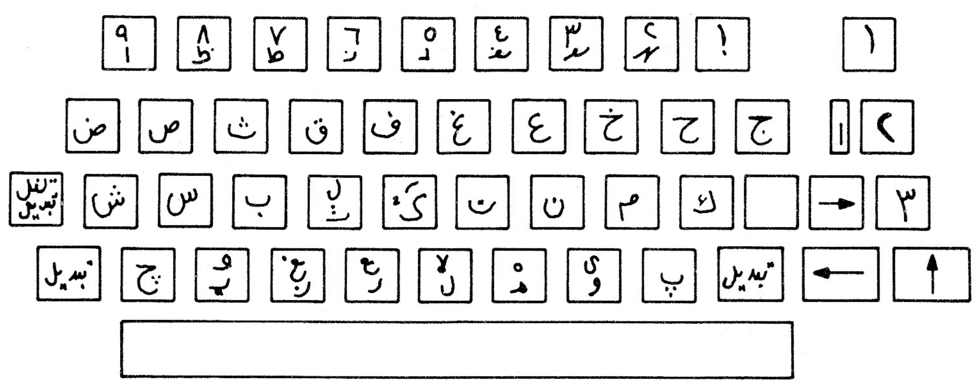


Fig. 12. NCR 395 typewriter keyboard for the Iranian language.

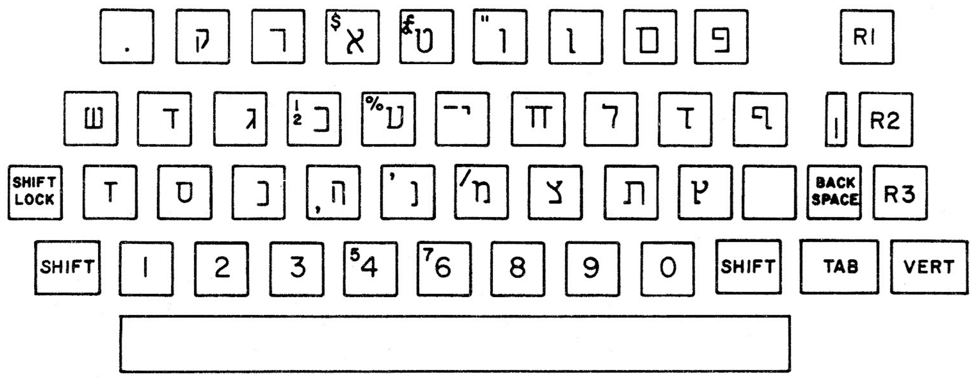


Fig. 13. NCR 395 typewriter keyboard for the Hebrew language.

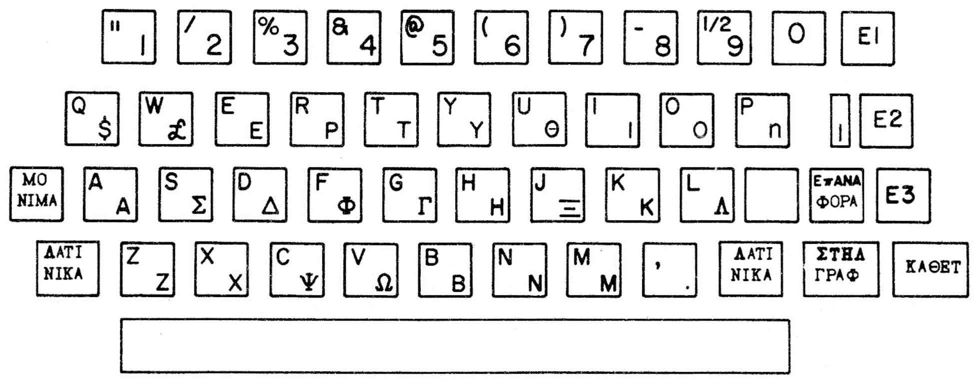


Fig. 14. NCR 395 typewriter keyboard for the Greek language.

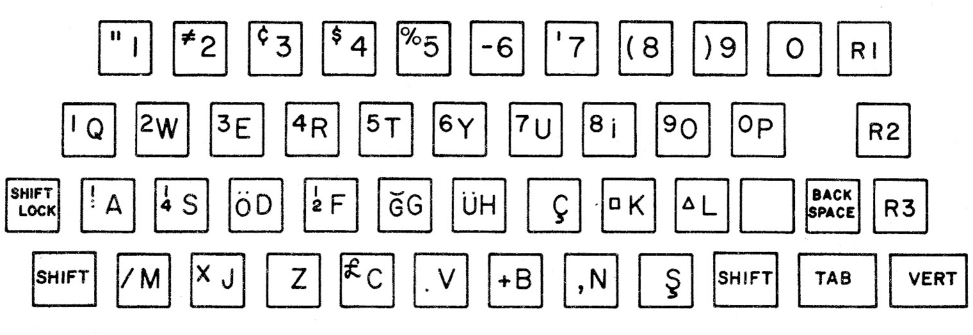


Fig. 15. NCR 33 typewriter keyboard for the Turkish language.

(Fig. 1), but not on the layout for the United Kingdom (Fig. 3). There are also wide variations among countries in symbol locations. The question mark (?) is found in different locations on the South African (Fig. 4) and French (Fig. 5) keyboards.

Graphic symbols are used more extensively in some regions than others. The labeling of the eject and open keys on the Latin American (Fig. 9) and American (Fig. 1) keyboards illustrates the contrast.

The NCR 399 system uses common sizes and arrangements of key tips for all regions except Japan (Fig. 10). On the Japanese keyboard two keys are omitted (upper right corner of typewriter cluster), and the resume and shift keys are shaped differently.

INTERNATIONAL STANDARDIZATION

The ISO, representing more than fifty national standardization bodies, has issued at least three ISO recommendations related to keyboards,

covering the layout of typewriter keys (R 1091), the numeric section of ten-key keyboards (R 1092), and certain key-tip symbols (R 1093). These were developed by the ISO Technical Committee on Office Machines (TC95) and approved by at least 60 percent of the national bodies. ISO recommendations are only guidelines. The only valid standard for a country is the national standard of that country.

1. *ISO Recommendation R 1091—Layout of Printing and Function Keys on Typewriters, 1st Edition, June 1969*. This recommendation defines the arrangement, number, spacing, and location of the printing keys and of some of the function keys on typewriters, irrespective of the size of the typewriter. The assignment of numeric and alpha characters to specific keys within the key layout is not part of the recommendation.

2. *ISO Recommendation R 1092—Numeric Section of Ten-Key Keyboards for Adding Machine and Calculating Machines, 1st Edition, June 1969*. This recommendation establishes the composition and layout of ten-key keyboards for adding and calculating machines, as well as the shape of the keys, the slope of the keyboard plane, the maximum keystroke, and the spacing of keys. It applies only to the numerical keys that constitute ten-key keyboards and not to function keys employed with such a keyboard.

3. *ISO Recommendation R 1093—Keytop and Printed or Displayed Symbols for Adding Machines and Calculating Machines, 1st Edition, June 1969*. This recommendation establishes keytop and printed or displayed symbols to be provided on adding machines and calculating machines. It does not prescribe the style of symbols.

A draft ISO proposal entitled, "Guidelines for the Harmonization of General Purpose Alphanumeric Keyboards," is in circulation. This proposal contains guidelines for the layout of general purpose alphanumeric keyboards when they are intended to implement sets of characters based on the Roman alphabet. Keyboard layouts complying with these guidelines will also conform to the requirements of draft ISO Proposal 2126 entitled, "Basic Arrangement for the Alphanumeric Section of Keyboards Operated with Both Hands." Proposal 2126 defines the arrangement of a basic core for the alpha-numeric section of keyboards. It is intended for keyboards to be operated by touch with two hands. In addition to the characters covered by Proposal 2126, the guidelines proposal specifies (1) the pairing and the allocation of a certain number of symbols and punctuation marks, and (2) the allocation to specific keys of additional alphabetic letters (national alphabetic extenders) when they are required, and/or of the separate diacritical or accent marks.

The European Computer Manufacturers Association (ECMA) is also involved with keyboard standardization. This organization published "ECMA Standard for Keyboards Generating the Code Combinations of the Characters of the ECMA 7 Bit Coded Character Set," Standard ECMA-23,

in June 1969.[2] This standard defines three keyboard layouts for data processing machines generating the code combinations of the ECMA seven-bit code. One layout, identified as Type A, is a ten-key keyboard with a very limited number of additional keys. It is for use with numeric data. The arrangement may be based on either ISO Recommendation R 1092, which has the adding machine numbering scheme, or the Consultative Committee on International Telegraphy and Telephony Recommendation E.161 for touch tone telephones.[3]

The Type B layout is for use with alphanumeric data that are predominantly numeric. A block of numeric keys (similar to the Type A layout) is located at the right hand end of the keyboard, and the remainder of the keyboard will be as similar as possible to the Type C layout.

The Type C layout is for use with alphanumeric data that are predominantly alphabetic. Its layout will be consistent with those in recommendations by the ISO Technical Committee on Office Machines.

ECMA Standard 23 does not define physical factors, such as key spacing, keyboard slope, size and shape of keytops, nor the way in which the keytops are labeled. ECMA has also proposed a Japanese Kana-alphabet standard for typewriter keyboards implementing 96 and 110 Katakana character sets.

COMMONALITY VERSUS CUSTOMIZATION

There are conflicting views on the advisability of providing a common or customized keyboard arrangement for each unique region. Where language and culture permit, keyboard commonality is advantageous for the user. It simplifies operation, minimizes the need for operator training and retraining on keyboards of different makes or types of machine, and facilitates the exchange of operators within and across national boundaries. The disadvantage of keyboard commonality is that concessions may have been made that reduce job performance and increase operator strain and fatigue due to unnecessary mental processing and unnecessary hand and finger motions.

For economic reasons, manufacturers of business equipment prefer to have a minimum number of specialized keyboards for a given machine. Each additional keyboard configuration costs money for tooling, manufacture, inventory, shipping, and the preparation of specialized training and maintenance manuals. If the potential market is large, the extra costs of customized keyboards can be amortized across many machines with a resultant low additional cost per machine. Customizing the keyboard layout for a country with a small market potential is less likely because the cost per machine can be significant. A critical question is: How much is it

[2]Copies of the ECMA-23 Standard are available from: European Computer Manufacturers Association, rue du Rhône 114, 1204 Genève, Switzerland.

[3]*Editor's note*: See the paper by Archbold in this volume.

worth to customize a keyboard arrangement for a country with limited sales potential?

The approach followed by some manufacturers has been to provide a basic arrangement of keys. The keys may be grouped in clusters, as, for example, the keyboard in Figure 1, based on logical sequences required by the principal applications. Special requirements of nations and regions are considered, and the key tips are marked with the appropriate characters in the language of the region. Sometimes, however, there are restrictions on the flexibility available to locate characters on keys. With some keyboard technologies, each key generates a unique code representing a character. It is not always economically feasible to transform a key code to represent some other character.

Recent technological developments may allow more keyboard customization than in the past. These developments include: (1) transparent key caps that permit interchangeable nomenclature; (2) removable key tips; (3) programmable machine logic that permits a key to change value through simple program and key tip changes; (4) key assemblies in which each key generates a unique, easily changeable code, permitting placement independent of key clusters; (5) key overlays that change the representation of keys according to the overlay; (6) function display keyboards where the key labels automatically change as transactions change; and (7) low-cost keyboards. These developments, however, reduce only some of the costs associated with customized keyboards. Other costs listed earlier must still be considered in any decision involving customization.

Still another consideration in this issue of customization is the number of national and international standards available or under development. As these recommendations become accepted, they must be considered in decisions about customization.

To sum up, the answer to the commonality versus customized approaches to keyboard layout must be sought on a case-by-case basis. In some companies, the solution is developed in trade-off studies. Human factors engineers contribute estimates of fatigue, strain, and performance effects, and customer acceptance; engineers provide technical feasibility and cost information; standards representatives provide information on international and national standards; and marketing representatives provide inputs about customer wants, competition, market potential, and the sensitivity of the market to the additional equipment costs that would be associated with a customized layout. Reaching a final decision about customization requires a judicious balancing of these several factors.

INTERNATIONAL GUIDELINES

The guidelines presented earlier for national keyboard arrangements have been applied to the layout of keyboards for a number of individual countries. The results appear to be satisfactory, although no formal evalu-

ations have compared this approach with other possible ones. Thus, very limited evidence suggests that arrangement guidelines developed for and effective in one nation or culture could be applied successfully in other nations and cultures. Problems may develop, however, when a keyboard must be operated in several regions because of the diverse requirements that may apply to those regions.

In addition to the national guidelines, at least four major guidelines apply to the arrangement of keyboards for international operation.

1. *Optimize the arrangement for each region.* Follow the guidelines presented in the section on national keyboard arrangement in arranging the keys for each region and application. Determine the best possible arrangement(s) for each nation or region independent of the other regions. If there is more than one best arrangement for a region, based on the use of a machine for several different applications, compare the arrangements to identify commonalities and important differences.

2. *Determine the minimum number of key-tip arrangements.* At this point, ignore key-tip legends and determine the minimum number of key-tip layouts that will satisfy the requirements of the various regions. Some important considerations are:

a. The area of the keyboard operated by touch is usually the most important from the standpoint of fatigue and performance.

b. If there is to be a typewriter section on the keyboard, design it to accommodate the maximum number of characters required by any of the countries. That maximum will usually be for a country with national alphabetic extenders, diacritical marks, and national symbols in addition to the basic alphabet.

c. For countries not requiring the extenders, diacritical marks, and special national symbols, the typewriter keys containing such symbols should be assigned to other symbols, controls, and functions having high frequencies of occurrence.

d. Follow international standards, if applicable, unless there is good justification for a different arrangement.

e. Arrange the remaining symbols, functions, and controls to follow the various national arrangements as closely as possible. Where discrepancies exist among countries, provide unique locations by country, if these discrepancies are important enough, or develop the best possible compromise. The compromise may be based on analyses of frequency of use (for example, one country may account for 80 percent of machine use), importance, or logical grouping of functions for all countries using the basic keyboard.

3. *Decide if customization is necessary.* Determine for each region whether fatigue, strain, or performance considerations are sufficient to justify a customized keyboard. The justification for a unique keyboard must be couched in language understandable by groups working toward maxi-

mum commonality. Of course, constraints imposed by keyboard technology may be a factor in establishing the number of unique arrangements possible. If the cost of flexibility is low, then more unique keyboards for a given machine may be possible. Note, however, that minimum retraining and capability for transfer of operators among countries are important user requirements. Keyboard customization for a region, even though economically feasible, may not be desirable from the user's point of view.

4. *Provide key-tip captions in the language of the operator.*

CONCLUSIONS

National guidelines for keyboard design have been applied in individual countries with reasonable success. However, keyboards for individual countries sometimes have variations in language or culture and in historical precedents that tend to interfere with international commonality. The successful development of international keyboards requires that these additional complexities be considered and any conflicts be resolved. International design guidelines have been proposed to aid in reaching a decision on keyboard customization or commonality.

A customized arrangement may be justified for a country if a common layout causes significant fatigue, strain, or performance decrement. However, there is a demand by some users to have an essentially common international keyboard arrangement for a class of machines when operator mobility exists within and among countries, and minimum retraining is important.

Manufacturers generally prefer to minimize the number of different keyboards for a given machine. Additional configurations increase costs that must be passed on to the customer. However, technological developments may make future keyboard customization less expensive than in the past. Even so, user demands for commonality to reduce transfer and retraining costs may result in keyboard commonality when the keyboard cost of customization would be economically feasible. The move toward commonality is bolstered by the interest in and development of international keyboard standards.

Users and manufacturers are becoming more aware of the contributions human factors engineers can make to the arrangement of international keyboards. It is likely that the human factors profession will be invited to participate in such activities even more in the future.

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